1990. Pages 235-270 *in* J. W. Everts, ed., Environmental Effects of Chemical Locust and Grasshopper Control. A Pilot Study. Food and Agriculture Organization of the United Nations. Project ECLO/SEN/003/NET. Rome.

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CHAPTER XII BIRDS

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Introduction

A plague of the Desert Locust (*Schistocerca gregaria*) occurred through the African Sahel between 1986 and 1988. Affected African countries responded by initiating surveillance and control programs with the assistance of international donors. A variety of insecticides were used in these programs, few of which had been evaluated for possible effects on Sahelian environments. Two commonly used compounds, fenitrothion and chlorpyrifos, have been shown to cause mortality in organisms on treated areas in North America.

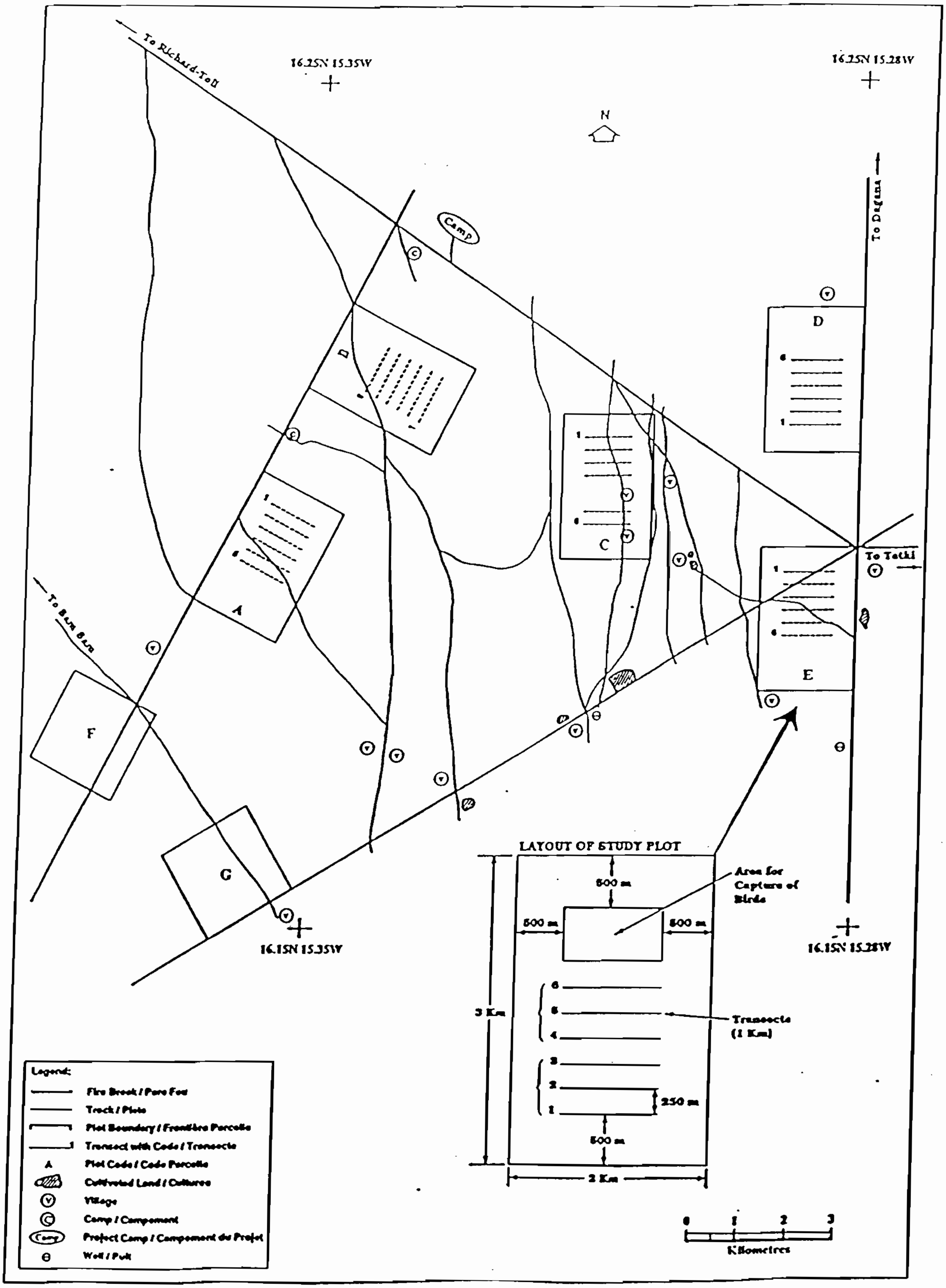
When applied to wetland habitats, chlorpyrifos has consistently caused mortality and other effects in aquatic invertebrates and fishes. In contrast, when used for insect control in terrestrial habitats, chlorpyrifos has not had severe effects on resident warm blooded animals (Odenkirchen and Eisler 1988).

Fenitrothion applications to forests in Canada at 300 g/ha and higher usually have had acute effects on passerines (Busby *et al.* 1983). Reductions in bird abundance were found at application rates of 140 to 280 g/ha, especially in canopy feeders (Pearce & Peakall 1977). Carcasses were recovered at the rate of 0.7 birds/h of searching after treatments of 560 g/ha. In addition, nest desertion by female White-throated Sparrows (*Zonotrichia albicollis*) increased from 12 to 58 percent after two applications totaling 630 g/ha (Peakall and Bart 1983). However, at an application rate of 300 g/ha in Scotland, Spray *et al.* (1987) did not find effects on the size of the breeding bird populations, on bird counts immediately before and after spraying, or on reproduction in Coal Tits (*Parus ater*). Of greater pertinence to locust control programs are the findings of mortality and decreases in bird abundance following applications of 210-420 g/ha of fenitrothion to rangelands in the western United States for grasshopper control (McEwen 1982).

Our studies of the effects on birds were part of a large, comprehensive study to evaluate the impact of experimental applications of fenitrothion and chlorpyrifos on aquatic and terrestrial habitats in northern Senegal. An experimental approach was chosen because it was impossible to predict when and where the insecticides would be applied for operational control of locusts. Thus, treatments were not made to areas containing locust swarms or bands; however, relatively high populations of grasshoppers (predominantly *Oedaleus senegalensis*) were present on treated areas.

Objectives of our bird studies were to assess treatment effects on bird abundance and mortality, on the foods eaten by birds, and on cholinesterase (ChE) levels in the brains of selected species. Bird populations could change due to either mortality or to movements from treated areas in reaction to reduced food availability. Food habit studies contributed to understanding effects of reducing insect biomass, and ChE measurements helped assess the intensity of insecticide exposure and the cause of death in birds found dead. In addition, attempts were made to evaluate the reproductive performance of several bird species on treated plots.

Figure XII.1: Layout of experimental plots.



Study Area

Plots and treatments

Five 2x3-km study plots, separated by at least 2 km (Fig.XII.1), were used to evaluate effects of four individual treatments on birds. Details on geology, vegetation, landscape and landuse and climate are given in Chapters I and II. The treatments that were assessed were fenitrothion (1F and 2F) and chlorpyrifos (1C and 2C) at the recommended and double rate for locust control respectively and an untreated control (Control). Details on the treatments are given in Chapter I. This pilot study was conducted primarily to observe the kinds of gross effects that took place and differences in the intensity of effects associated with the different chemicals and application rates. It was decided to use our research capabilities to differentiate among the variables of chemicals and rates. In the future, long-term work will be needed to examine experimentally the more important effects identified in this pilot study.

Methods

Bird counts on transects

To help assess treatment effects on bird numbers, six 1-km transects were established 250 m apart in each of the five study plots (Fig. XII.1). Along each transect, a tree or shrub was marked with white paint every 100 m. Bird counts were taken on most transects and plots each week between 24 July and 7 October (Table XII.1).

Table XII.1: Time Schedule of Counts

	Week of										
	July		August				September				October
	23	30	6	13	20	27	3	10	17	24	1
Count	1	2	3	4	5	6*	7-	8	9	10	11
							Treatments				

* Three transects per plot.
\- Only 3 transects on plot C.

Plots were visited in about the same sequence each week. During counts on a plot, each of two observers recorded birds on three transects. Counts were begun at 0700h and completed at about 1000h each day. During 50 minutes on each transect, birds heard or seen within 50 m of the transect were tallied. A constant pace was maintained by covering each 100 m of the transect in 5 minutes. Our counts did not always measure bird densities, as they were designed to provide only indices to bird abundance. However, for many larger species (e.g., Abyssinian Rollers *Coracias abyssinica*), average numbers per transect tallied approximate densities per 10 ha.

Birds flying over transects were tallied as were others, especially large birds such as raptors, that flew from the transect well ahead of the observer. Secretive and nocturnal birds were seldom recorded, and counts did not evaluate treatment effects on these species.

While establishing plots, common species were seen or heard sufficiently often to enable future identification during counts. For others, positive recognition required more time and varied with observer experience and ability. Such problems did not greatly influence the counts of common birds that were ultimately used to evaluate treatment effects. Counts provided indices to species abundance, and differences in observers' abilities were not important as long as each observer's ability remained relatively constant over time.

Bird counts in depressions

Three to five of the depressions in each plot were selected for monitoring bird abundance in the unique habitat found in depressions. One to four 15-minute counts were obtained in each depression both before and after treatments. An observer sat or walked around and through depressions while noting the birds present. Such counts were taken between 1000 and 1300 after transect counts.

Evaluation of breeding performance

Singing Bush Larks.

Larks (*Mirafra javanica*) bred throughout the study area during the period of our investigations. Singing males were one of the most common birds seen on transects as they hovered above breeding territories and nests located within grasslands. Special searches were conducted to increase the number of known nests, while others were found during counts on transects. To prevent nest detection by predators, we did not approach closer than 1 m while marking nests with stakes and checking them to determine the number of eggs, young, and fledglings. These records were obtained before treatments of plots, but were not continued because nesting success was too low to enable assessment of treatment effects.

Buffalo Weavers.

Colonies of Buffalo Weavers (*Bubalornis albirostris*) were present throughout the study area primarily in large Baobabs and acacias. The status of a number of colonies was noted during bird counts on each plot. Colonies were characterized as being in a state of courtship, nest building, incubation, or feeding young. As colonies and bird behavior were easily observed, activities in colonies were recorded before and after insecticide applications to assess treatment effects on weaver reproduction.

Nest boxes.

To explore the value of nest boxes in measuring the impact of insecticide treatments on hole-nesting species, 33 boxes were attached to trees in two plots. Fifteen were placed in plot 2C on 18 August before chlorpyrifos was applied and, on 20 August, 18 boxes were set out in the control area. The boxes were about 20 x 20 x 30 cm, with an entrance hole of 5 to 6 cm in diameter, and with a detachable top. Boxes were placed at least 100 m apart at a density of about 1 box per 4.5 ha.

Searches for dead or debilitated birds

Searches.

To measure any direct mortality from treatments, special carcass searches were organized. Twelve young men were recruited from nearby camps and villages. It was anticipated that these Poular herdsmen, who spend their lives herding livestock and observing activities in the savannah, could provide the most complete searches for dead and debilitated birds. Two searches were conducted on each of the four treated plots: one at 24 h and another at 48 h after treatments. Two additional searches were carried out on plot 2F at 3 days and at 6 days following fenitrothion applications. Identical searches were made on plot C (control plot) during the same period on 2 consecutive days. In each search, the 12 men, supervised by an assistant, spread out 20 m apart over a distance of 250 m and walked abreast for 2.0 km during a period of 2 to 3 h, depending on the density of vegetation. Searchers covered 8.3 percent of the area within each plot and searched 1.3 - 1.9 ha/h/person.

Search efficiency.

On two occasions a number of dead birds were placed in an area to be searched in order to establish search efficiency. The search team was not informed of this prior to counts. On 7 September, before the 48-h search in plot 1F, 4 Singing Bush Larks, 22 Buffalo Weavers, and 10 Golden Sparrows (*Passer luteus*) were put out in the area. (The carcasses used were the birds that were killed for ChE measurement.) Each species was placed in a habitat where it likely could have died. The birds were labeled to distinguish them from birds that may have died from spray applications. On 13 September, during the 24-h search in plot 2F, 1 Abyssinian Roller, 1 Singing Bush Lark, 58 Buffalo Weavers, and 1 Golden Sparrow were placed in the search area. After the searches, remaining marked carcasses were not removed but were left to help evaluate subsequent searches.

The search efficiency was needed to calculate the proportion of the population killed (Fite *et al.* 1988). Separate efficiency coefficients were calculated for small birds (weight < 30 g) and larger birds.

Carcass disappearance rate.

Dead birds were also used to determine the disappearance rate of carcasses due to scavenger activity. Both search efficiency and a disappearance rate need to be known in order to make a reliable estimation of mortality following a treatment. On 5 September, 5 Buffalo Weavers and 9 Golden Sparrows were placed at five locations along a transect in plot 1C and were checked after 24 and 48 h. On 13 September, 33 Buffalo Weavers were placed in plot 2F at seven locations along a transect. They were checked after 24, 48, and 72 h. The disappearance rate was used to calculate the proportion of carcasses remaining ($R = 1 -$ disappearance rate). This was also used in calculating the proportion of the population killed (Fite *et al.* 1988).

Collections for food habits and cholinesterase analyses

Collections.

Singing Bush Larks, Buffalo Weavers, and Golden Sparrows were initially chosen for monitoring changes in cholinesterase (ChE) levels and food habits following treatments. These species were abundant, widely distributed, and ranged in food habits from insects to seeds. It was found that Golden Sparrows decreased rapidly in numbers after rains started and they were deleted from collections. As Abyssinian Rollers, Hoopoes (*Upupa epops*), and Woodchat Shrikes (*Lanius senator*) proved susceptible to treatments, they were added for collection. Birds primarily were taken with mist nets, a 4.5-mm air rifle, and a 16-gauge shotgun. For each species an attempt was made to collect 10 individuals in the first and third week after treatments in treated plots. Birds from untreated areas were taken for controls. Birds found dead or debilitated during searches were also saved for analyses.

Specimen handling.
Live specimens were killed by thoracic pressure and were subsequently dissected. In a few cases, specimens were frozen from 1 day to 2 weeks before they were dissected. Each specimen received a field collection number, and information on the bird was noted in a field collection log. Body masses were taken using spring scales with a precision of 0.3 percent. Body masses below 30 g were rounded to the nearest 0.5 g, and body masses above 30 g, to the nearest gram. During dissection birds were sexed and aged. The size of gonads and other information on breeding condition, like presence of a brood patch, were noted when relevant. In a number of cases, the amount of subcutaneous fat was estimated using a score from 0 (no fat) to 4 (maximum fat deposits). The gizzard (and crop, if present) was removed, and the contents or the complete gizzard was stored in ethanol (96 percent) in a small vial. Information on the amount of food was noted; gizzards that were completely empty were discarded. Brains were removed and placed in 15-ml scintillation vials, labeled with cryolabels, and subsequently stored in liquid nitrogen until they could be processed in the laboratory.

Voucher specimens were labeled and stored as flat skins or preserved in 96 percent ethanol for deposition in the Field Museum of Natural History (FMNH) in Chicago, Illinois, U.S.A. In the Museum, tentative identifications were verified, specimens were assigned to species or subspecies, and recent fledglings were confirmed by the presence of a bursa fabricii (S. M. Goodman, FMNH, *in lit.*)

Food habits analysis.
Gizzard collections were transported to the Department of Toxicology, Wageningen Agricultural University, The Netherlands. The contents were identified using a low-power binocular microscope with 7-40x magnification. Identifications were usually performed to the level of Orders. Often specific remains were used for identification and counting (e.g., Orthoptera jaws and Coleoptera headparts). All remains were tallied, and the number of prey items present was calculated. The presence of grit was also noted.

In calculations, the number of prey items and their relative occurrence were compiled. Using numbers of food items as a basis for determining food habits tends to bias results in favor of the small, numerous items. However, the procedure was satisfactory for comparing the kinds of foods eaten before and after insecticide applications.

Cholinesterase analysis.
Brains were transferred to storage in a laboratory freezer after fieldwork was completed. They were held in the freezer for about 2 months and analyzed over the next 6 weeks. ChE activity was determined by the colorimetric method of Ellman *et al.* (1961) as modified by Hill and Fleming (1982). Analyses were conducted by Prof. Mounirou Ciss and

Dr. Boubacar Niane (Chapter III). Results are expressed as μ moles of acetylthiocholine iodide hydrolyzed per minute per gram (wet weight) of brain tissue (μ moles/min/g).

Statistical analyses

The experimental design for this study did not include replications of treatments and, therefore, it did not fulfill theoretical requirements to permit general inferences from the results. However, analyses were conducted with the understanding that any differences detected could be due either to the effects of the chemicals, to inherent differences among plots, or to both factors.

Analyses of bird count data were made for the sum of 71 selected species, the sum of 21 selected species, and for 22 individual species, using a two-factor, repeated measures ANOVA with unbalanced data. Analyses were conducted for birds grouped by taxonomic and life history traits using a three-factor, repeated measures ANOVA with unbalanced data. Data were unbalanced because several counts on some plots were conducted by only one of the two observers.

Differences between plots and -within plots- between weeks, in the proportion of grasshopper remains in gizzards of selected species, were tested separately in single classification ANOVAs. The same analysis was conducted to test differences in body masses of captured specimens between and within plots. Means were separated with Duncan's Multiple Range test.

Results

Bird counts on transects

More than 120 species of birds were identified on the study plots between June and October (Annex XII.1). Some identification was tentative as individuals were seen only a few times, at a distance, or when visibility was poor. Afrotropical species (both residents and intra-African migrants) dominated the avifauna in June and July, but palearctic migrants increased in August, September, and October. Some species populations presumably were composed of both resident and migrant individuals. It was sometimes unclear whether increases observed over time were the result of local movements or of an influx of palearctic migrants. Observations on the control plot and other untreated areas showed that normal increases and decreases in certain species occurred unrelated to insecticide treatments.
Counts on study plots were conducted during and after the rainy season (July, August, September). Some birds had reproduced during the dry season (Abyssinian Rollers), while others initiated breeding with the beginning of the rains (Singing Bush Larks, Buffalo Weavers, Blue-eared Glossy Starlings *Lamprocolius chalybaeus*, Cricket Warblers *Prinia clamans*, and Fantail Warblers *Cisticola juncidis*).

Some of the species seen on study plots were not used in the assessment of treatment effects. Many species were not known to be exposed to insecticides and could not be viewed as reliable indicators of treatment effects. These included wide-ranging species (raptors), migrating species (swifts), and those such as sandgrouse and aquatic species traveling over plots to distant water sources. A few species were considered incidentals, as they were rare and seldom seen. All birds in these categories and all palearctic migrants, most of which arrived after treatments, were not considered in evaluating treatment effects. Golden Sparrows were so numerous that changes in their abundance were capable of masking effects on the less abundant species if included with the others in compilations of total birds present. Therefore, data for this species were considered separately. Golden Sparrows were seen both on transects and flying over transects, and decreased naturally during the course of the study (Fig. XII.2).

The removal of the above birds left 71 species (designated by a single asterisk in Annex XII.1) for consideration in assessing insecticide applications. Of the 71, 21 species (designated by a double asterisk in Annex XII.1) were common on plots. Totals of the 71 species, the 21 species, each of the 21 species, and of Golden Sparrows (both on transects and over transects) were compiled for each transect. Means and standard errors for transects on each plot and each count are presented in Appendices 6 through 30. To determine whether life history characteristics of the 71 species made them more or less sensitive to treatments, analyses were conducted based on taxonomy (2 groups), macrohabitat (2 groups), feeding stratum (2 groups), and foods (3 groups) (see Annex XII.1).

The total number of birds (sum of 71 species) and the total of the most common species (sum of 21 species) decreased after treatments ($p < 0.01$). The percentage decrease in bird numbers was greatest on plot 2F and was greater on all treated plots than on the control plot (Table XII.2). In general, a greater decrease in bird numbers on plot 2F was indicated by all assessments ranging from the sum of 71 species (Fig. XII.3), the sum of 21 species (Fig. XII.4), and the life history traits of birds (Figs. XII.5a, 5b, 5c) to many of the individual species, such as the Singing Bush Lark (Fig. XII.6).

There were significant ($p \leq 0.02$) interactions between counts and plots for 6 of the 22 species analyzed individually. Examination of data showed that interactions for Blue-eared Glossy Starlings, Golden Sparrows, and Grey Hornbills (*Tockus nasutus*) were not related to treatments. Mean separation tests indicated Abyssinian Rollers, Blue-naped Mousebirds (*Urocolius macrourus*), and Singing Bush Larks responded in the same way to treatments. In comparison to the control plot, their numbers temporarily decreased after treatment on plots 1F and 2F. By week 11 there were no real differences among plots in numbers of these three species.

Abyssinian Rollers increased during the study (Fig. XII.7), but by the third week after treatment (week 10), roller numbers on all treated plots were significantly ($p = 0.01$) lower than on the control plot. Blue-naped Mousebirds also tended to increase during the first 8 weeks of the study (Fig. XII.8), especially on plots 1C and 2C, which by the eighth week had significantly higher numbers than the control plot ($p = 0.01$). In contrast, on plots 1F and 2F, mousebirds numbers had dropped to zero 1 week after treatments. Singing Bush Larks were the second most abundant birds on plots (after Golden Sparrows). They likely were a good indicator species of treatment effects in the savannah; they were abundant, widely distributed, sedentary, and nesting in the grasslands. After treatments, lark numbers decreased on all plots as young fledged and birds presumably left the area. However, decreases were greatest and occurred more rapidly on plots 1F, 2F and 2C, all of which on the first or second week after treatment had significantly ($p < 0.01$) fewer larks than the control plot (Fig. XII.6).

Figure XII.2: Changes in average numbers per transect of Golden Sparrows in the control area seen flying over transects or feeding on transects. For comparison the average numbers of the 71 most common species are given as well.

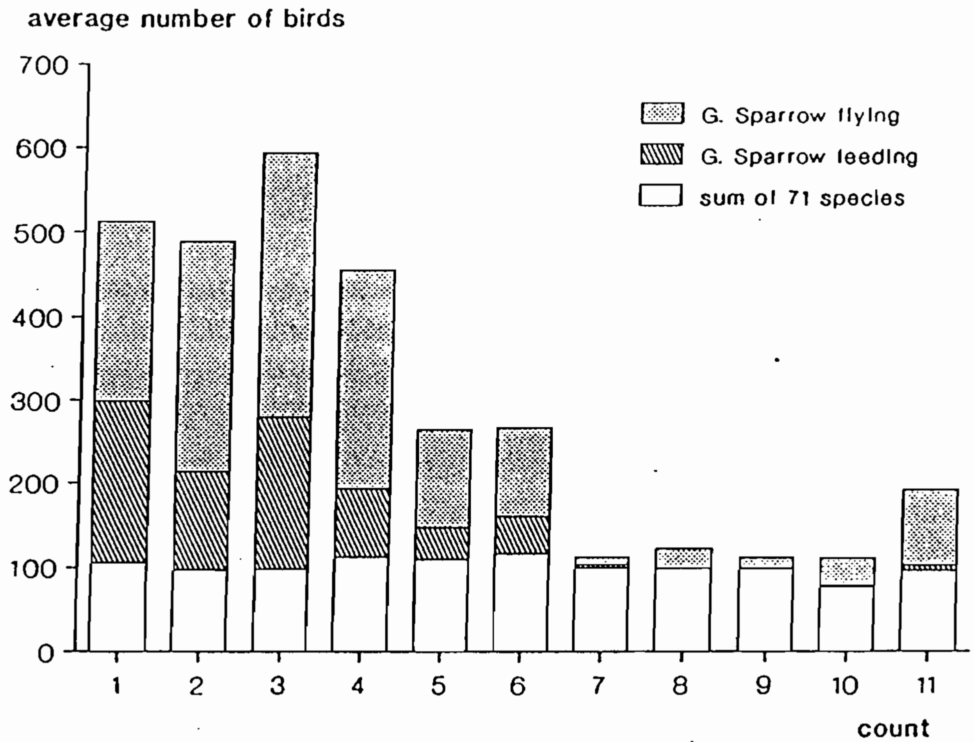


Table XII.2: Percent change in bird numbers between periods on study plots.

Data and means compared	Plot 1C	2C	1F	2F	Control
Sum of 71 species					
Pretreatment *vs.* posttreatment	-26	-28	-30	-46	-8
Count 6 *vs.* posttreatment	-26	-26	-42	-61	-14
Sum of 21 species					
Pretreatment *vs.* posttreatment	-26	-28	-32	-51	-13
Count 6 *vs.* posttreatment	-24	-26	-46	-63	-16

Figure XII.3: Average number per transect of 71 species seen during each count on experimental plots. An arrow indicates the moment of treatment.

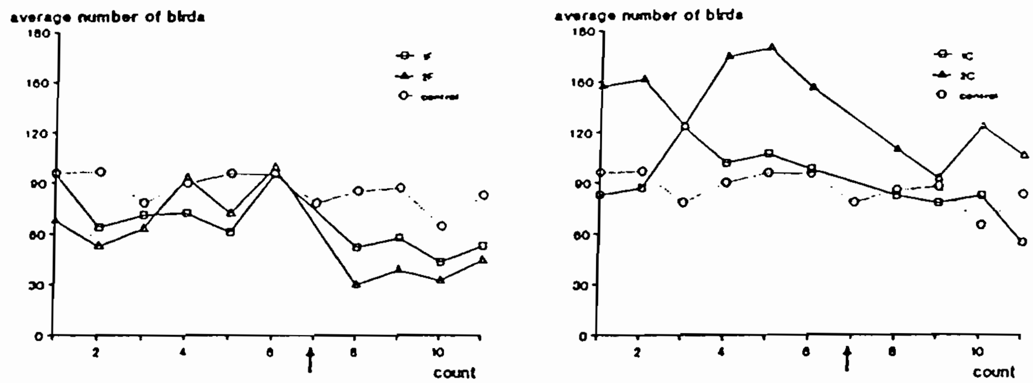
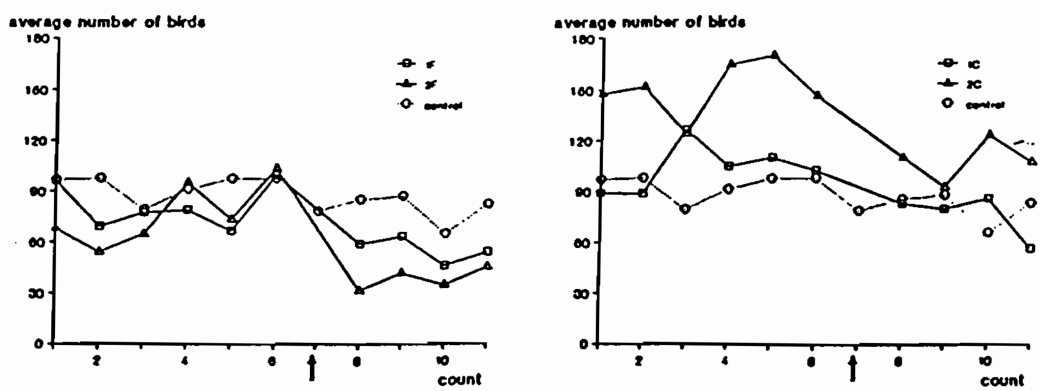


Figure XII.4: Average number per transect of 21 species seen during each count on experimental plots. An arrow indicates the moment of treatment.



Figures XII.5a-c: Average number per transect of insectivores and vegetarians (A), savannah and depression birds (B), and terrestrial and arboreal feeding birds (C) seen during each count on experimental plots. An arrow indicates the moment of treatment.

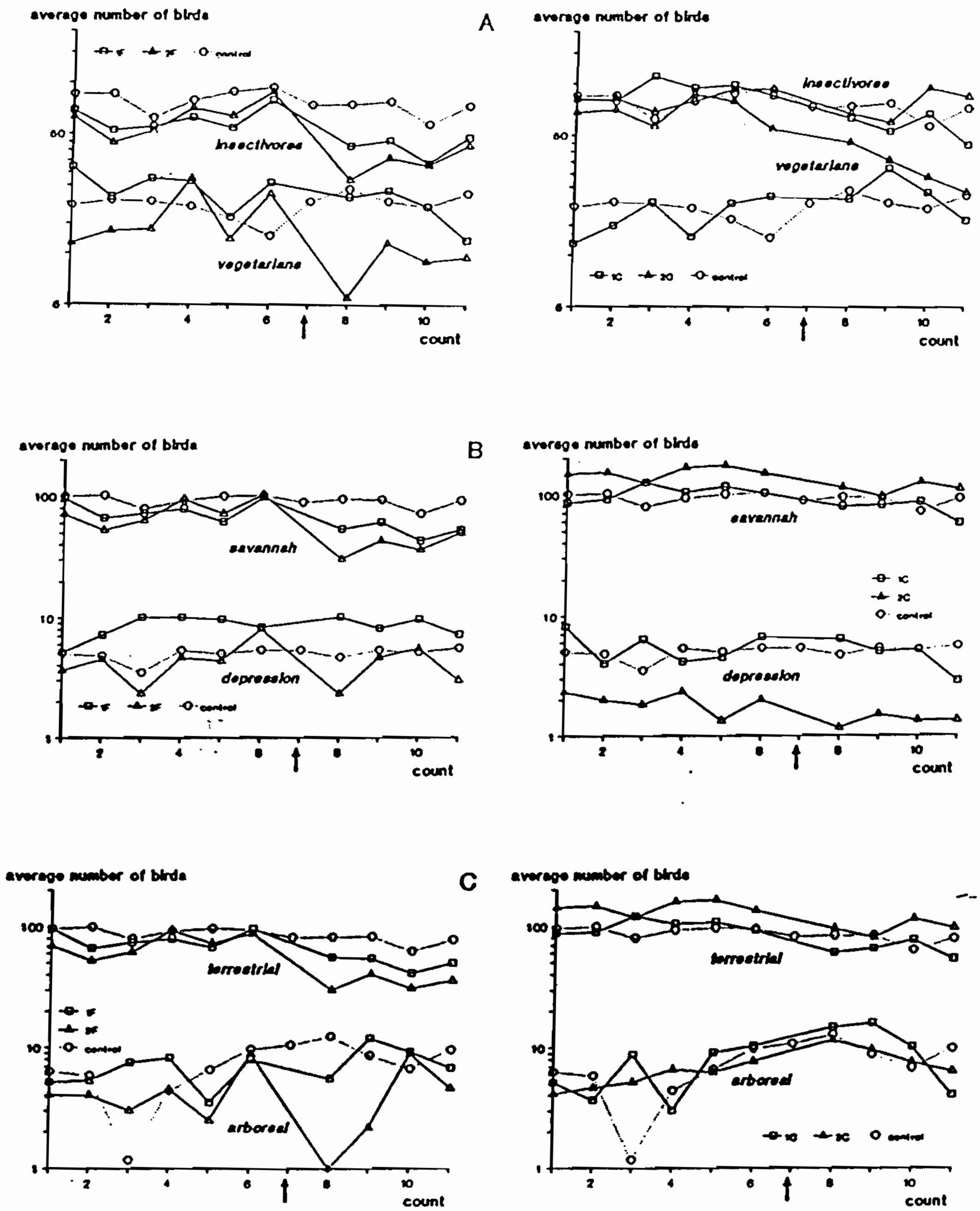


Figure XII.6: Average number per transect of Singing Bush Larks seen during each count on experimental plots. An arrow indicates the moment of treatment.

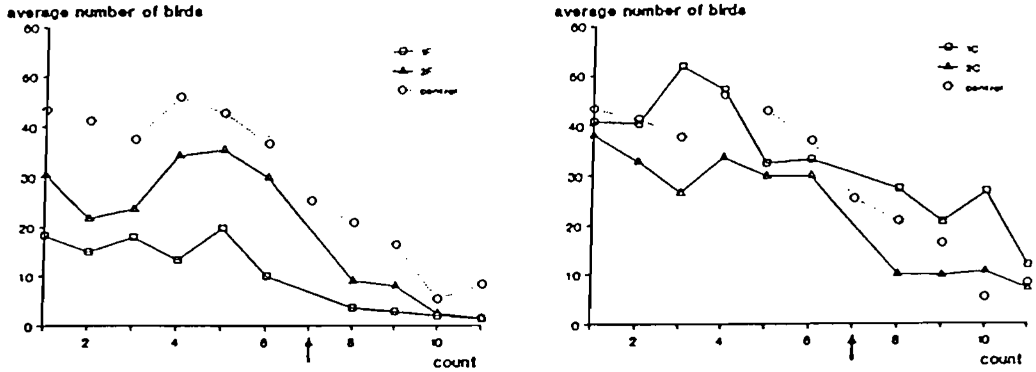


Figure XII.7: Average number per transect of Abyssinian Rollers seen during each count on experimental plots. An arrow indicates the moment of treatment.

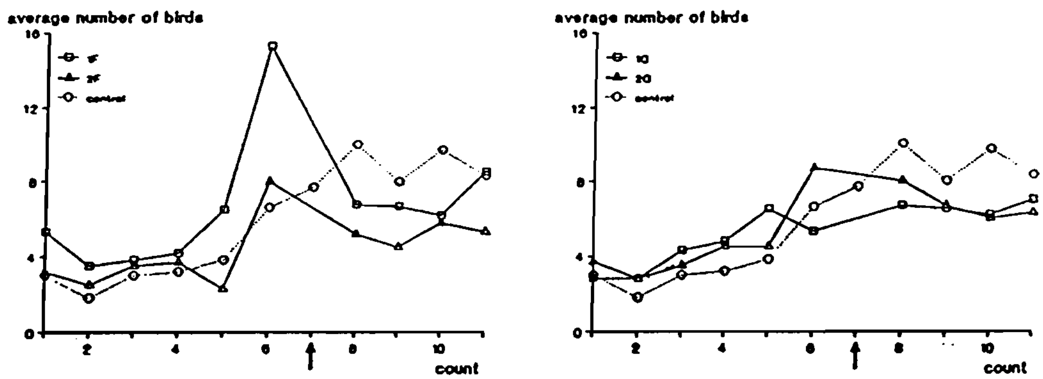


Figure XII.8: Average number per transect of Blue-naped Mousebirds seen during each count on experimental plots. An arrow indicates the moment of treatment.

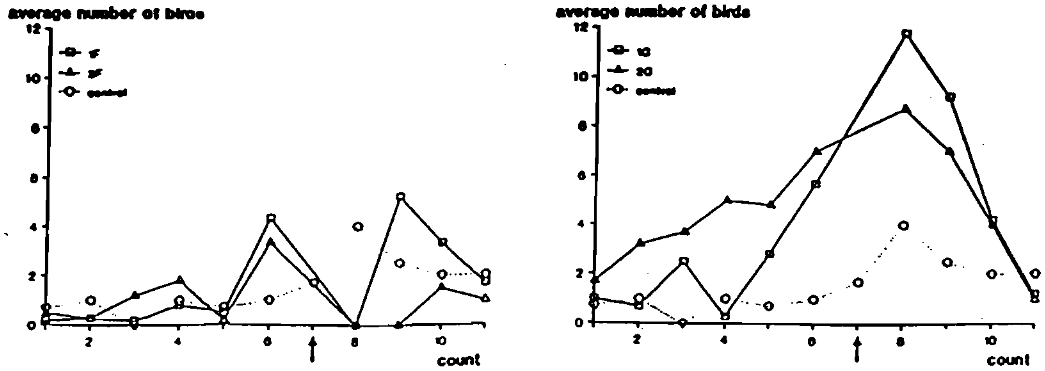
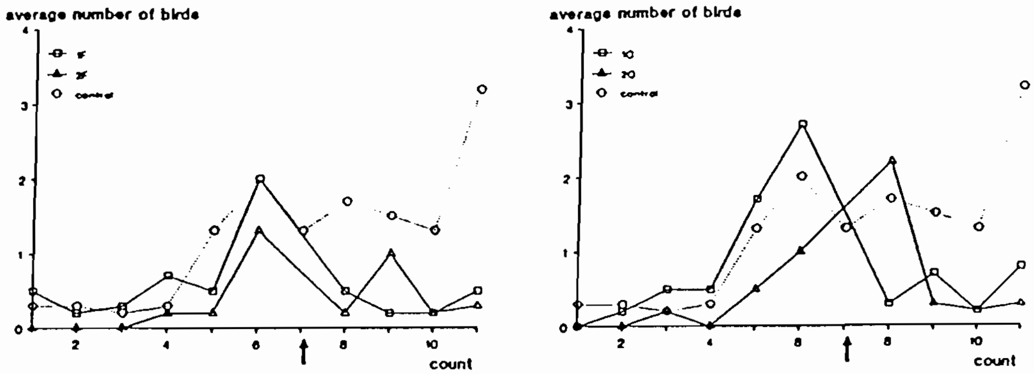


Figure XII.9: Average number per transect of Hoopoes seen during each count on experimental plots. An arrow indicates the moment of treatment.

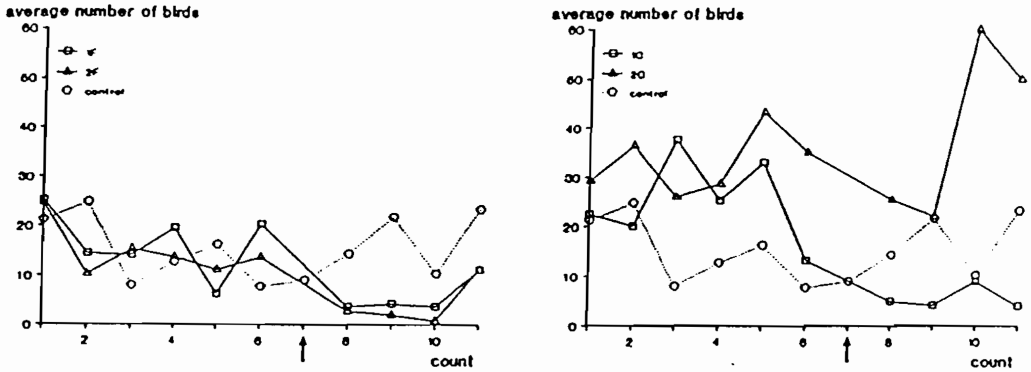


Interesting, but nonsignificant, changes were documented after treatments in numbers of Hoopoes and Buffalo Weavers on treated plots. Hoopoes increased in the general study area up until insecticide applications. During the next 4 weeks, numbers on treated plots decreased and were usually lower than on the control plot (Fig. XII.9). Hoopoe numbers were highly variable among transects and plots, and differences were not significant ($p = 0.12$).

Buffalo Weavers were highly gregarious and were most often seen flying between colonies and feeding areas, the location of which varied over time. Counts of weavers frequently changed erratically on transects, probably depending on whether they fed near transects or whether feeding flight lines crossed transects. Buffalo Weavers were often seen in flocks, locally following terrestrial movements of grasshoppers. Weavers decreased on treated plots immediately after insecticide applications (Fig. XII.10). Although these changes were not significant ($p = 0.11$), they provided a strong indication of of a treatment effect. Weavers had gathered into colonies before treatments. On treated plots, all colonies monitored (3 or 4 per plot), except one on plot 2C, were deserted after treatments. Colonies on the control plot persisted, one until 27 September.

Dove abundance did not change appreciably on most plots after spraying, but numbers of Pink-headed Doves (*Streptopelia roseogrisea*) on plot 2C dropped considerably during weeks 8 through 11 (Annex XII.10). These decreases were not significant, but may have been real as observers independently recognized and commented on the general decrease in Pink-headed Doves on plot 2C. Before treatments, all doves tended to be more abundant on plot 2C than elsewhere. A nearby water well used daily by local inhabitants provided a dependable water source to support doves. After rains, a source of water may have been less critical, and grass seed production elsewhere in areas receiving earlier rains may have provided better food resources.

Figure XII.10: Average number per transect of Buffalo Weavers seen during each count on experimental plots. An arrow indicates the moment of treatment.



Golden Sparrows were apparently not affected by treatments; however, their numbers decreased significantly ($p = 0.01$) on all plots over time (Figs. XII.11 and 12). They constituted 80 percent of total birds seen on the control plot during the first five counts and only about 30 percent during the last four counts (Fig. XII.2). Their decrease was correlated with breeding elsewhere in the region and with the growth of new annual grasses in the study area, which may have restricted their ability to forage for seeds on the ground. Sparrows were increasing during our last counts as grasses dried and a new crop of seeds ripened. At that time flocks consisted largely of recently fledged birds.

Figure XII.11: Average number per transect of Golden Sparrows seen during each count on experimental plots. An arrow indicates the moment of treatment.

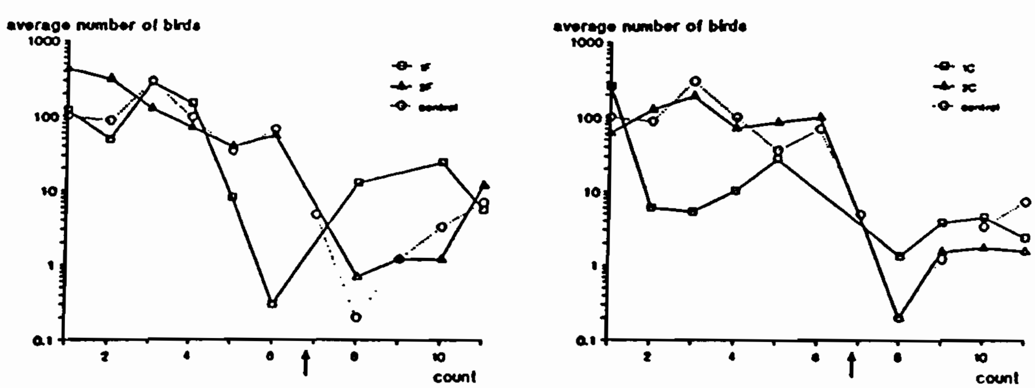
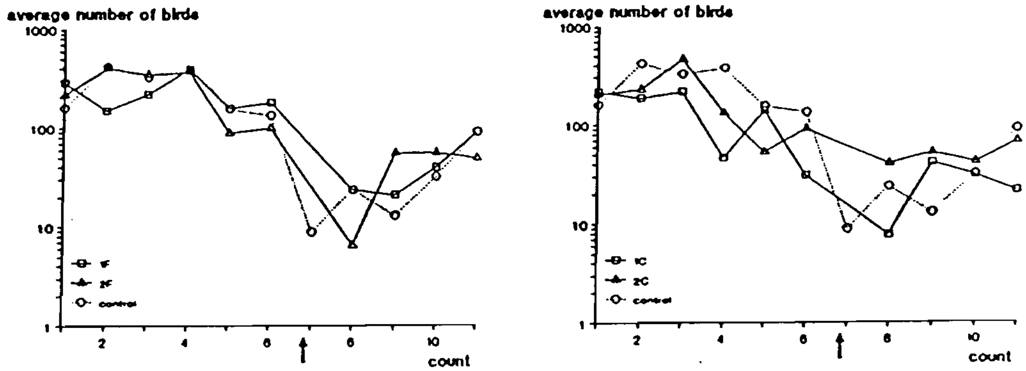
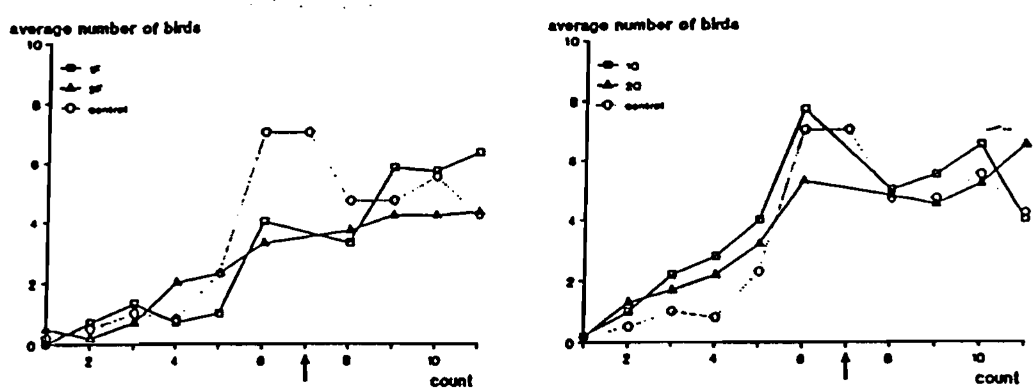


Figure XII.12: Average number per transect of Golden Sparrows seen during each count flying over experimental plots. An arrow indicates the moment of treatment.



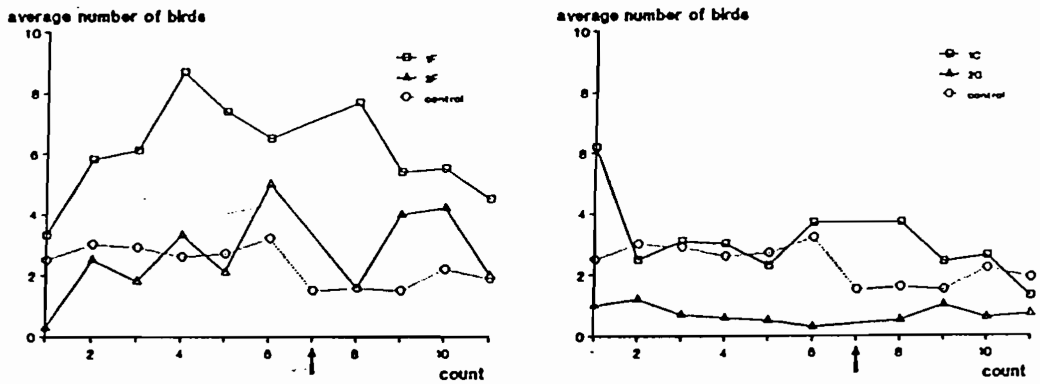
In contrast to Golden Sparrows, Woodchat Shrikes greatly increased on plots during the study period but, like sparrows,- the shrikes were not apparently affected by treatments. The Woodchat Shrike precedes all other palearctic migrants in autumn (Morel and Roux 1966). Shrike numbers gradually increased through week 6 (Fig. XII.13). After treatments, shrike numbers on all plots remained somewhat stable, suggesting that they already had reached their winter density. Cricket Warblers also increased during the study and did not appear to be affected by insecticide treatments (Annex XII.25). Increases partly were due to the appearance of young with adults; the Cricket Warblers bred during the period of the study.

Figure XII.13: Average number per transect of Woodchat Shrikes seen during each count on experimental plots. An arrow indicates the moment of treatment.



Other afrotropical species that were widely distributed and bred during the study period did not appear affected by insecticide treatments. Numbers of Black Bush Robins (*Cercotrichas podobe*) ($p = 0.03$), Grey-backed Camaropteras (*Camaroptera brachyura*) ($p < 0.01$), and Fantail Warblers ($p = 0.07$) varied among plots and over time, but not in relation to treatments (Fig. XII.14). These species were considered obligate depression species, and the lack of an effect on them suggests the depression habitat was not affected by spraying to the same degree as the savannah habitat (see also Fig. XII.5b).

Figure XII.14: Average number per transect of Black Bush Robins, Grey-backed Camaropteras, and Fantail Warblers seen during each count on experimental plots. An arrow indicates the moment of treatment.



Effects of fenitrothion were indicated, especially on plot 2F, for most groups of birds whether separated on the basis of taxonomy, food habits, or feeding stratum (Table XII.3). This suggests that these traits did not predispose birds to fenitrothion effects. In contrast to birds on the control plot, those on fenitrothion plots tended to decrease after treatments regardless of their taxonomic position or their life history traits (except that depression species increased). This situation probably reflects the fact that birds are somewhat opportunistic in their choice of foods. The abundance of grasshoppers on plots (see Chapters VII and VIII) may have supported high bird populations. Reduction of that food source, therefore, could have caused some birds to leave plots.

Table XII.3: Percent change in numbers of birds grouped by taxonomic and life history traits on control and fenitrothion plots.*

Traits	Plot 1F	Plot 2F	Plot Control
Taxonomy			
Passerine	-39	-67	-12
Nonpasserine	-40	-65	+91
Habitat			
Depression	+32	-67	+12
Savannah	-72	-81	+24
Feeding stratum			
Terrestrial	-42	-60	+10
Arboreal	-34	-78	+76
Food habits			
Insectivores	-20	-54	+77
Omnivores	-54	-74	-20
Granivores/frugivores	-38	-66	+89

Percent difference between birds seen during Count 6 (last pretreatment count) and Count 8 (first pretreatment count).

A normal variation was observed among plots in the abundance of certain species (Table XII.4). These differences were not related to treatments, but undoubtedly reflected the preference of birds for habitat resources on specific plots. Such habitat preferences were not identified, but such variations in the abundance of a species among plots illustrate why replication of plots is necessary in experimentation. Resources affected by insecticide treatments were not uniform among plots, so the possibility of each treatment's effect on birds was not equal. Replication of plots increases the probability that variations in resources and thereby in the kinds and numbers of birds will be equally tested against each treatment.

Table XII.4: Variations among plots in the numbers of birds of selected species.*

Species	Plot 1C	2C	1F	2F	Control
Namaqua Dove	13	61	26	19	19
Vinaceous Dove	3	15	10	5	7
Pink-headed Dove	26	231	37	19	44
Laughing Dove	8	23	13	4	9
Blue-naped Mousebird	7	18	2	4	3
White-throated Bee-eater	8	14	2	4	7
Red-beaked Hornbill	2	0.5	6	3	2
Singing Bush Lark	207	160	84	137	209
Chestnut-backed Finch Lark	15	11	24	16	4
Chestnut-bellied Starling	9	19	22	10	12
Black Bush Robin	2	2	6	2	5
Fantail Warbler	13	1	23	9	8
Buffalo Weaver	138	164	80	75	83

* Values are the totals of Counts 1-5 on each plot for each species. Highest value for each species is underlined.

Table XII.5: Total numbers of birds seen during depression counts.*

Plots	1C		2C		1F		2F		Control	
Species	Pre (10)	Post (5)	Pre (10)	Post (3)	Pre (8)	Post (3)	Pre (9)	Post (7)	Pre (14)	Post (5)
Namaqua Dove	1	1	2	4	-	-	12	-	8	-
Vinaceous Dove	7	1	1	3	1	1	-	5	4	-
Pink-headed Dove	2	1	8	1	4	-	3	4	6	8
Laughing Dove	6	4	-	3	3	-	-	2	6	2
Blue-naped Mousebird	8	1	10	8	-	-	7	3	2	-
White-throated Bee-eater	-	11	1	2	1	-	1	1	14	22
Abyssinian Roller	11	7	5	5	9	3	3	4	11	12
Red-beaked Hornbill	1	-	-	-	7	2	2	-	3	-
Woodchat Shrike	10	3	8	1	3	5	5	1	1	10
Blue-eared Glossy Starling	6	1	2	5	3	1	1	-	9	1
Chestnut-bellied Starling	1	17	3	2	2	-	1	3	22	-
Black Bush Robin (d)	10	3	10	6	6	1	6	1	11	3
Fantail Warbler (d)	4	1	-	-	7	2	3	5	4	1
Camaroptera (d)	1	2	5	6	4	1	8	1	10	6
Long-tailed Beautiful Sunbird	10	1	4	-	9	-	7	2	4	4
Vitteline Masked Weaver (d)	10	1	11	5	1	1	9	-	13	16
Buffalo Weaver	1	-	8	-	8	-	4	-	22	14
Total	88	54	78	46	68	17	72	32	150	99
Average	9	11	8	15	8	6	8	5	11	20
Change (%)	+20		+88		-25		-38		+82	

* Number of counts in parentheses. "Pre" indicates pretreatment, and "post," posttreatment.
(d) indicates birds are depression species; other species also used savannah habitats (ds or s species).

Bird counts in depressions

A total of 55 species of birds was seen during depression counts, including incidentals and palearctic migrants. Of these, only 17 species were relatively abundant (Table XII.5). There were large variations in counts, both within individual depressions and among different depressions. Numbers of observations were too few to test for significant changes due to treatments. Still, it was of interest that the data, when compiled, suggested the same detrimental effects of fenitrothion as indicated by transect counts and other observations. Whereas depression counts in the control and chlorpyrifos plots indicated an increase in total birds present after treatments, numbers in fenitrothion plots apparently decreased. These findings do not conflict with the increase in depression species shown in Table XII.3. Counts in depressions reported here included all birds that were seen in depressions and were not limited to only the obligate depression species.

These results again suggested that fenitrothion treatments decimated food resources to a much greater extent than chlorpyrifos treatments. In contrast to transect counts, depression counts on the chlorpyrifos plots and the control plot suggested bird numbers increased. Birds on those plots may have used the verdant depressions more frequently as the savannah habitat dried following the rainy season.

Evaluation of breeding performance

Singing Bush Larks.

Twenty-eight lark nests were located during searches. Virtually all nests had the entrance facing a northerly direction. Once this feature was identified, nests were found more easily. Information on the nests, as well as on the calculation of the breeding success, is given in Annex XII.2.

Records for the complete nesting cycle were obtained for only a few nests. Therefore, Mayfield's (1961) method was used to calculate breeding success. With this approach the probabilities for nest, egg, and nestling survival were calculated based on the number of days each nest was under observation. Combining these figures gives the probability for a single egg to produce a fledgling.

The probability of nest survival during the incubation period was 16-24 percent (4 nests were destroyed by predators; 2 nests were deserted; while in 5 new nests, no eggs were detected despite the observation of birds on the nests). The probability of nest survival during the nestling period was calculated to be 53-59 percent, with 3-5 nests destroyed by predators. Egg survival was 94-100 percent, and nestling survival appeared to be 92-93 percent. Combining these probabilities, the total production for the entire duration of the nest is between 7 and 13 percent. In other words, for each 100 eggs laid, only 7-13 produced a fledgling. It is unknown whether our activities, despite precautions, may have contributed to this low breeding success.

Buffalo Weavers.

Frequently colonies of Buffalo Weavers were established, became involved in early reproductive behavior, and then were deserted. Others lacked synchrony, with nest building occurring in colonies where young were being fed. In some, successive cohorts of young were produced; these often were large colonies and, of course, were very productive. It was impossible through casual observation to monitor the establishment, progress, and success or desertion of colonies. However, records were maintained for a number of active colonies observed during the first 5 and last 4 weekly transect counts on each plot. These records documented the locations of colonies, their desertion, and in many cases their reestablishment. The number of colonies active before and after treatment compared to the total initiated are shown in Table XII.6.

Table XII.6: Occupancy rate of Buffalo Weaver nesting colonies before and after treatment of plots.*

	Plot				
	1C	2C	1F	2F	Control
Period					
Prespray (end of August)	3/6	5/7	3/6	2/4	3/6
Postspray (mid-September)	0/6	2/7	0/6	0/4	3/6

* Data represent number of active colonies/total number of colonies initiated on plot.

Most colonies on treated plots were deserted at about the time of spraying. Observations were insufficient to determine if desertion was due to treatments, but results indicated insecticides may have caused these changes. Some evidence suggested that, during applications, areas containing colonies that persisted on plot 2C were not sprayed.

Nest boxes.
A complete nest was built in 9 of the 33 nest boxes set out. In an additional 7 boxes, nests were started, but not completed. Of the 9 completed nests, 1 was built by Blue-eared Glossy Starlings, 5 by Red-beaked Hornbills (*Tockus erythrorhynchus*), and 3 by Grey-headed Sparrows (*Passer griseus*). Nesting success was poor. Four of the 5 hornbill nests were destroyed by Peulh children from a nearby village. The fifth hornbill nest was in plot 2C and contained four young when last checked on 12 October. Of the Grey-headed Sparrow nests, one produced a single fledgling; another was deserted before egg laying. The third, in plot 2C, was successful, but the number of young fledged was not determined. The Glossy Starling nest in the control plot produced one fledgling.

Searches for dead and debilitated birds

Searches.
A few dead or debilitated birds were found in all treated plots (Table XII.7), while none were located in the control plot. The greatest number and variety of birds were found in plot 2F, which had been treated with 825 g ai/ha of fenitrothion. Button Quail (*Turnix sylvatica*), Abyssinian Rollers, Hoopoes, and Singing Bush Larks were most frequently affected on plots. Searchers captured a number of fledglings from the ground, and these also were predominantly Singing Bush Larks. These were likely affected by treatments, based on the ChE analyses.

Table XII.7: Dead (D) and debilitated (d) birds found on plots after treatment.*

	Plot			
Species	1F	2F	1C	2C
Button Quail	-	2(d)	1(d)	-
White-throated Bee-eater	-	-	-	1(d)
Abyssinian Roller	1(d)	1(d)	-	3(D)
Hoopoe		1(D)	2(d)	--
Singing Bush Lark	1(D)	1(D)	-	1(D)
Tree Pipit		-	1(d)	--
Woodchat Shrike	-	2(d)	-	-
Cricket Warbler	-	1(d)	-	-

* Fledglings of the Long-tailed Beautiful Sunbird (2), Buffalo Weaver (1), Singing Bush Lark (28), Pink-headed Dove (1), and Black-headed Shrike (1) were picked up during searches. Results of ChE analyses suggest that at least a number of these birds were debilitated, rather than simply flightless (see text).
Two fledgling larks and one fledgling Pink-headed Dove and no dead or debilitated birds were found on the control plot.

Search efficiency.
Of the 22 Buffalo Weavers placed in the search area of plot 1C, 9 (42 percent) were found, while only 2 (14 percent) of 14 Singing Bush Larks and Golden Sparrows were located. These results and the fact that vegetation was more dense on most other plots prompted us to intensify the searches by increasing search time from 1 h to 1.5 h per km. In plot 2F, 33 (57 percent) of 58 Buffalo Weavers were recovered, but none of the other three carcasses (roller, lark and sparrow) were located. After 24 h, another search was made, and 7 more weavers and a roller were found, giving a total recovery of 69 percent for larger birds. A third search after 48 h did not produce additional carcasses. Calculated efficiencies are given in Annex XII.3.

Carcass disappearance rate.
Of 9 sparrows and 5 weavers put out on plot 1C, 1 sparrow and 2 weavers (total of 22 percent) disappeared within 24 h. After 48 h, most carcasses contained fly larvae. In plot 2F, none of 33 weavers were missing after 24-, 48-, and 72-hour checks, and there was little evidence of sarcophagic fly and beetle activity. For calculations it was assumed that the proportion of carcasses remaining on plot 2C was the same as on 1C, and on plot 1F the same as on 2F. Therefore, the proportion of carcasses remaining was taken to be 1.0 on plots 1F and 2F, and 0.8 on plot 2C (Annex XII.3).

Population mortality.
Values for calculation of mortality in large (> 30 g) and small (< 30 g) species populations of savannah birds are given in Annex XII.4. Mortalities calculated on plots 1F, 2F, and 2C are given in Table XII.8. In plot 1C, only one debilitated bird was found, and population mortality was not calculated. Calculated population mortality was low on all plots. Mortality was not sufficiently high to account for decreases observed in bird numbers on transect counts.

Table XII.8: Calculated minimum mortality (percent) of the bird populations occurring in savannah habitat due to treatment with insecticides (see Appendix 4).

	Plot*		
Size of birds	1F	2F	2C
> 30 g	2	7	2
< 30 g	7-9	6-13	3-10

* Insufficient numbers of birds were found on Plot 1C to calculate mortality.

Collection of birds

The sex, age, and breeding condition of birds collected are listed in Annex XII.4. Buffalo Weavers, Abyssinian Rollers, Singing Bush Larks, and Golden Sparrows made up of most of the individuals collected. Brains and gizzards were saved from most birds to enable ChE and food habits analysis, respectively. Gonad condition indicated clearly that Buffalo Weavers were breeding in August and September. Most Abyssinian Rollers were immature birds and were not in breeding condition. Larks were in full breeding condition throughout the study period as were most Golden Sparrows. Many juvenile sparrows, apparently produced after rains had started, were mixed with adults in the population.

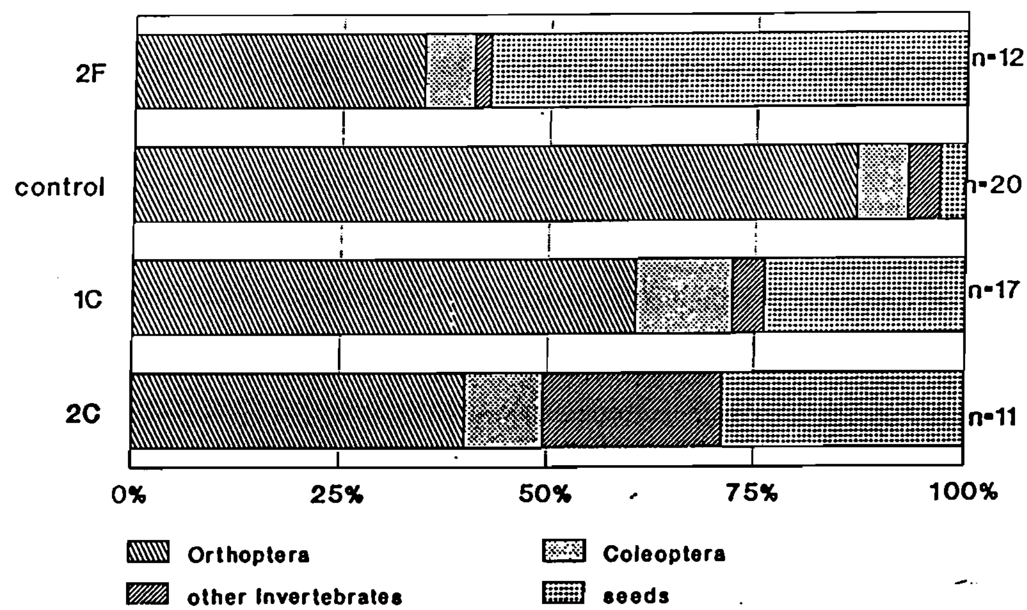
Food habits analyses

Numbers of items found in gizzards of birds collected posttreatment on study plots are shown in Annex XII.5. From these data certain inferences can be drawn on differences in foods eaten by several birds after insecticide applications.

Singing Bush Larks.

The percent composition of Singing Bush Lark gizzard contents, based on numbers of food items, is shown in Figure XII.15. The Singing Bush Lark showed a clear response to treatment in its feeding behavior. In the control areas, food items consisted predominantly of grasshopper larvae, with seeds present in only two of the 18 gizzards containing food (11-percent). In the sprayed plots, however, 17 of 38 gizzards (45 percent) had seeds in them. The proportion of Orthoptera in the gizzard remains from the control areas was statistically greater ($p < 0.05$) than in the chlorpyrifos and fenitrothion plots (plots 2C and 2F).

Figure XII.15: Percent composition of various foods in gizzards of Singing Bush Larks on experimental plots after treatments (based on numbers of food items in gizzards).



There were no apparent differences in prey selection between adults and fledglings. There was, however, a marked difference in the presence of grit in gizzards between adults and juveniles. In juvenile birds, 16 of 25 gizzards (64 percent) contained 1 to 25 small stones (maximum weight 0.25 g/gizzard), while in adult birds only 4 out of 33 birds (12 percent) contained grit in the gizzard.

Flightless fledgling Singing Bush Larks were significantly heavier ($p < 0.05$) in the control than in the treated plots, while among treated plots there were no significant differences in body masses. There were no significant differences in adult lark body masses between control and treated plots.

Abyssinian Rollers.

Treatment effects were not obvious in Abyssinian Roller gizzard contents (Fig. XII.16). Grasshoppers made up 60-95 percent of all prey remains that were identified. The main species was probably *Oedaleus senegalensis*, but *Acrida bicolor* and *Cataloipus cymbiferus* were incidentally identified in the prey remains. Based on the size of the jaws, predominantly adults or subadults were eaten. Four rollers that were found dead or debilitated 24 h after spraying (1 in plot 1F and 3 in plot 2C) had 35, 32, 29, and 51 grasshoppers, respectively, in their gizzards. In contrast, up to 14 grasshoppers were found in each of the nine rollers from the control plot and up to 19 grasshoppers were found in each of the 39 gizzards collected in treated plots. An immediate shift to feeding on dead or dying grasshoppers and rapid intoxication is likely, therefore, to have been responsible for the observed direct effects on Abyssinian Rollers in the study plots. A comparison of the relative proportion of the different prey items in roller gizzards between week 1 and week 3 posttreatment (Fig. XII.17) shows a decreasing proportion of grasshoppers present in treated plots and a stable proportion in the control. However, because of large individual variation, decreases were not statistically significant.

Abyssinian Roller body masses were not significantly different in control and treated plots. There were also no significant differences in body masses of rollers between week 1 and week 3 posttreatment.

Buffalo Weavers.

Treatments had little effect on gizzard contents of Buffalo Weavers (Fig. XII.18). Orthoptera were an important prey of Buffalo Weavers, making up 25-90 percent of the total remains present in individual gizzards and averaging 35-70 percent. Apparently, Buffalo Weavers were opportunistic feeders, adapting rapidly to the prey that was locally available. Birds from a colony at the project camp, used as controls, showed a dramatic shift in their diet within 1 week (Fig. XII.19). Therefore, it was more difficult to determine if changes in diet were an effect of treatments. Like Abyssinian Rollers, the Buffalo Weavers had a lower proportion of Orthoptera in their diet in week 3 than in week 1 posttreatment (Fig. XII.19), but changes were significant ($p < 0.05$) only in plot 2C.

Adult female Buffalo Weaver body masses decreased significantly ($p < 0.05$) from week 1 to week 3 posttreatment in both plots 2C and 1F. No changes were observed in the control plot; insufficient data were available from other plots to examine possible effects. Information on food habits of other species found dead or debilitated or otherwise obtained is summarized in Annex XII.6.

Figure XII.16: Percent composition of various foods in gizzards of Abyssinian Rollers on experimental plots after treatments (based on numbers of food items in gizzards).

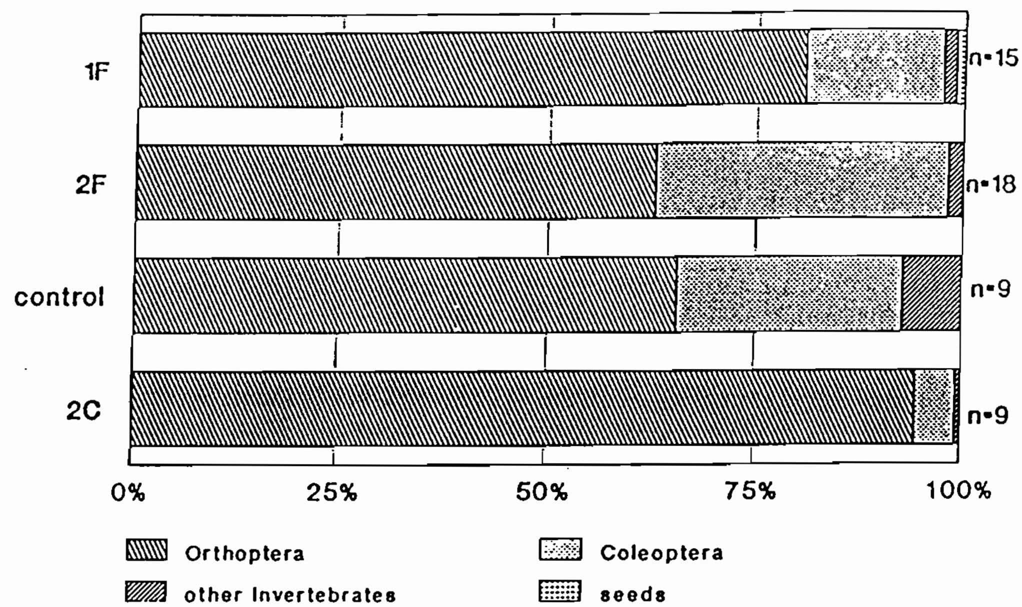


Figure XII.17: Percent composition of various prey in gizzards of Abyssinian Rollers on experimental plots at 0-1 weeks and at 3 weeks posttreatment (based on numbers of prey in gizzards).

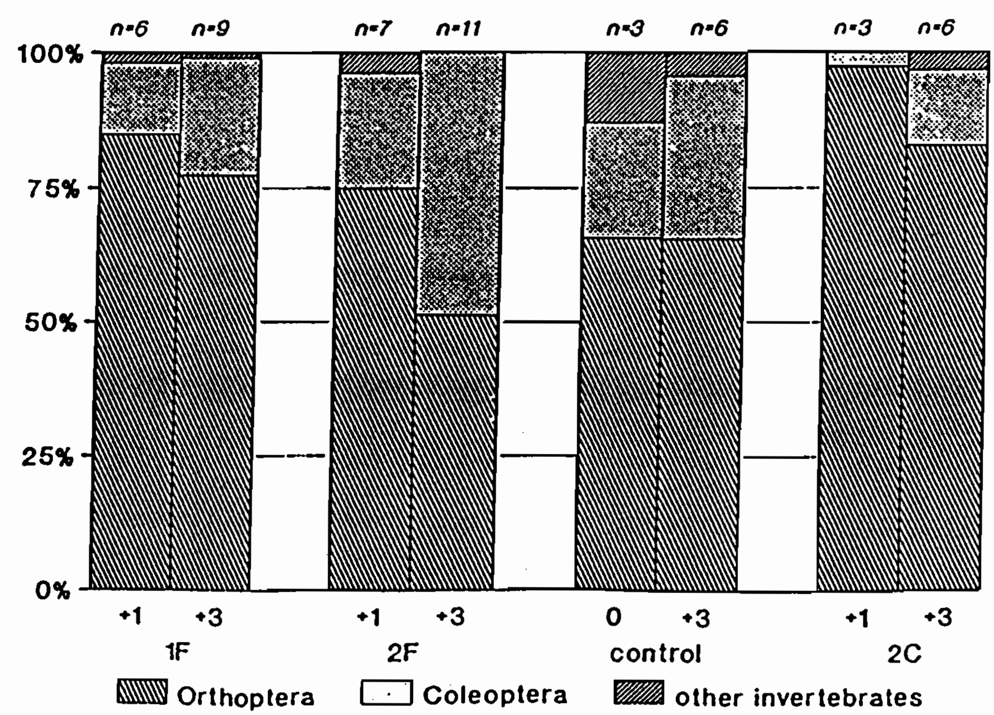


Figure XII.18: Percent composition of various foods in gizzards of Buffalo Weavers on experimental plots after treatments (based on numbers of food items in gizzards).

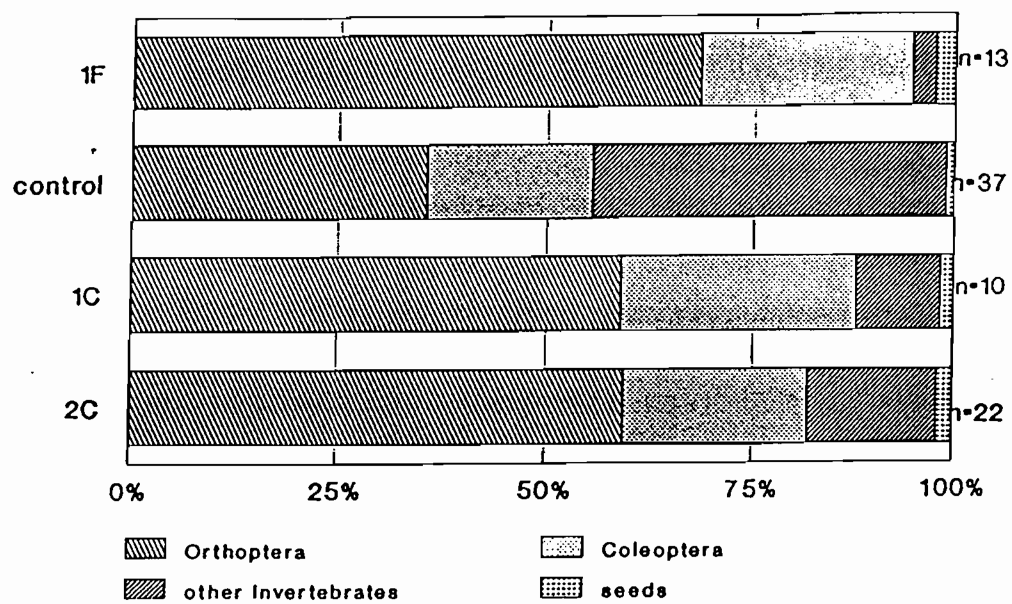
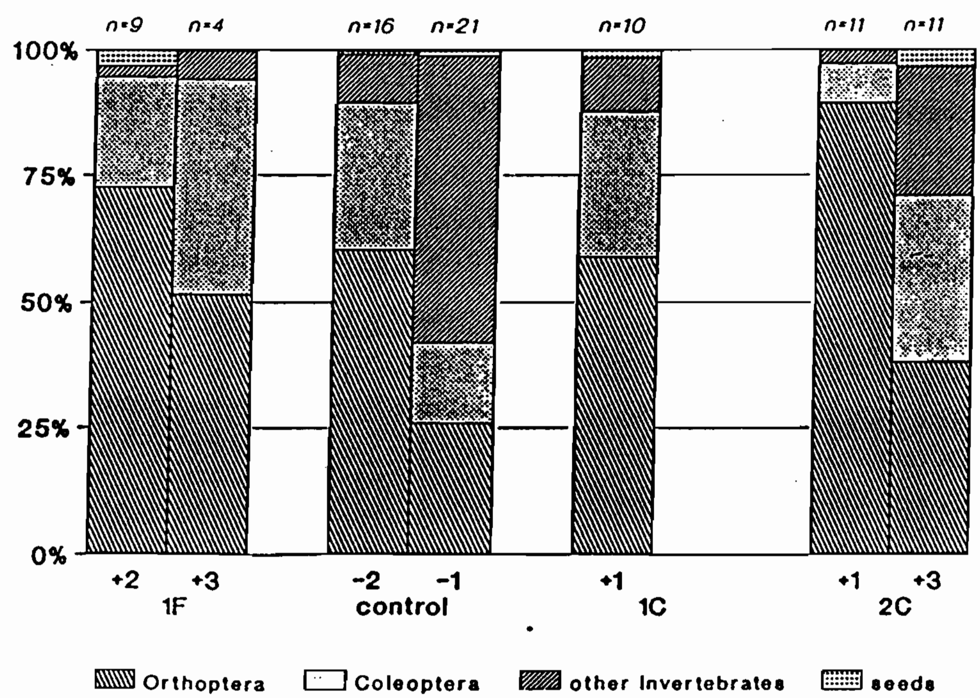


Figure XII.19: Percent composition of various foods in gizzards of Buffalo Weavers on experimental plots before and at 1 to 3 weeks after treatments (based on numbers of food items in gizzards).



Cholinesterase analyses

Brain samples were stored in liquid nitrogen from the time they were collected until mid-September. The method of analysis and the results are given in Chapter III. Because of sample losses, adequate numbers of unexposed birds were available for only two species--Abyssinian Rollers and Singing Bush larks. After treatments, Singing Bush Larks, Abyssinian Rollers, and Buffalo Weavers were the principal species collected. Buffalo Weavers decreased on all plots, except plot 2C, and were very difficult to collect, especially on plot 2F. Likewise, Singing Bush Larks decreased on all plots, and adequate collections were not always obtained. The problem of maintaining systematic collections on plots as bird abundance decreased due to treatments was not anticipated and was one of the lessons learned during this pilot study.

Dead and debilitated birds found on plots immediately after treatments (Table XII.7) had low ChE levels in their brains (Table XII.9). Compared to unexposed birds (Table XII.10), ChE levels were sufficiently inhibited to have caused death and debility of the birds. ChE levels also were low in fledglings found by searchers. In the young larks from plot 2F, ChE ranged from 6.32 to 16.27 mol/min/g; lowest levels were in birds found 72 h after treatment. ChE levels in brains of fledgling larks from all plots were well below those in adult larks (x = 40.0) and in one fledgling (29.9) from untreated areas (Table XII.10). This suggested that lark fledglings were impaired by exposure to insecticides, but -except in one bird- their normal ChE levels were not determined.

ChE inhibition of 50 percent or more is accepted as severe and is considered diagnostic as the cause of death in dead birds (Hill and Fleming 1982). Debilitated adult birds and fledgling larks in plots 1F and 2F showed an inhibition greater than 50 percent compared to controls. ChE inhibition was not as severe in dead birds found in plots 1C and 2C.

Live birds collected from plots 1 week after treatments often had lower ChE levels than controls, but after 3 weeks ChE levels in birds from treated plots were about the same as those in controls (Table XII.10). ChE inhibition usually was not severe in live birds collected from plots after treatments, but Singing Bush Larks collected 1 week after treatment of plot 2F showed a 50 percent inhibition. After 1 week, Abyssinian Rollers on plots 1F and 2F had ChE levels in the same range as those in rollers found dead on plot 2C. One Red-beaked Hornbill, shot three days posttreatment on plot 2F, had a low ChE activity (16.6 μ moles/min/g) compared to a control level of 27.8 in this species in Kenya (Bruggers *et al.* 1989).

Bird identification verification

Ninety bird specimens were shipped to the Field Museum of Natural History in Chicago where they were examined by S. M. Goodman. For ten specimens additional information on specific or subspecific identity was provided; a number of other identifications were verified. In addition, birds not sexed in the field were sexed, when possible, at the Museum.

A series of slides and color prints of Beaudouin's Snake Eagle (*Circaetus gallicus beaudouini*) was examined by Dr. J. M. Thiollay, Paris, and identifications were verified.

Table XII.9: Brain cholinesterase levels (μ moles/min/g) in brains of individual dead (D) and debilitated (d) birds and in groups of fledglings found on plots after treatments.*

	Plot			
Birds	1C	C	1F	2F
Button Quail	-	-	-	5.2 (d) 6.2 (d)
Abyssinian Roller	-	20.5 (D)	5.1 (d)	- 16.5 (D)
Hoopoe	-	-	-	8.6 (d) 7.9 (d)
Singing Bush Lark	-	23.5 (D)	-	-
Woodchat Shrike	-	-	-	11.2 (d) 7.7 (d)
Fledglings				
Bush Larks				
24 h	(4) 20.1 5.8	(2) 16.2 0.9	-	(4) 11.6 2.4
48 h	(2) 15.9 5.9	(2) 20.5 0.4	(2) 16.8 0.5	(3) 12.6 3.2
72 h	-	-	-	(3) 7.9 0.8
Buffalo Weaver				
24 h	-	(1) 15.5 0.0	-	-
Pink-headed Dove				
24 h	-	(1) 18.5 0.0	-	-

* See Table 35 for ChE levels in control birds. For fledglings, n is given in parentheses before means, and standard errors follow means when pertinent.

Table XII.10: Brain cholinesterase levels (μ moles/min/g) in live unexposed (control) birds and in birds collected on study plots after treatments.

Species and period posttreatment	1C (n)	1C $\bar{x}$	1C SE	2C (n)	2C $\bar{x}$	2C SE	1F (n)	1F $\bar{x}$	1F SE	2F (n)	2F $\bar{x}$	2F SE	Control (n)	Control $\bar{x}$	Control SE
Abyssinian Roller															
1 week	(1)	30.7	0.0		-		(4)	21.3	1.2	(5)	27.1	2.5	(5)	34.2	3.4
3 weeks		-		(1)	46.4	0.0	(6)	37.4	5.2	(10)	34.8	3.5		-	
Bush Lark (adult)															
1 week	(7)	33.1	3.8	(2)	32.0	7.5		-		(4)	20.8	1.7	(7)	38.4	4.6
3 weeks		-		(4)	41.1	4.5		-			-			-	
Bush Lark (juv.)															
1 week	(2)	18.5	7.5		-			-		(1)	15.2	0.0	(1)	29.9	0.0
Buffalo Weaver															
1 week	(8)	30.6	2.7	(10)	32.4	2.1	(7)	22.0	2.2	(1)	14.4	0.0	(2)	26.2	3.7
3 weeks		-		(9)	29.5	2.2	(1)	54.2	0.0		-			-	
Golden Sparrow															
3 weeks		-			-		(1)	38.8	0.0		-		(2)	31.1	1.1
Woodchat Strike															
3 weeks		-		(2)	28.6	2.3		-			-			-	
Red-beaked Hornbill															
3 days		-			-			-		(1)	15.2	0.0		-	
Hoopoe		-			-			-			-		(2)	37.3	0.4
Pink-headed Dove		-			-			-			-		(1)	20.8	0.0

Discussion

The varied and abundant avifauna on study plots provided an excellent situation for study of insecticide effects on the habits and population abundance of diverse species. Total bird numbers (sum of 71 species) decreased on all plots after treatments. Some of this decrease was due to bird mortality, but most apparently represented movement of birds from plots. Mortality, debility, and decreases in bird numbers were greatest on plots treated with fenitrothion. Decreases in Abyssinian Rollers, Blue-naped Mousebirds, and Singing Bush Larks were statistically significant, but decreases were also indicated in numbers of Hoopoes and Buffalo Weavers. Fenitrothion treatments caused decreases in these species and, in addition, reduced numbers of birds grouped on the basis of either their taxonomic position or life history traits.

Insecticides kill insects and other arthropods, reducing the food supply of birds. Decreases in bird numbers observed on study plots probably were largely due to such decreases in food. Results suggested fenitrothion more effectively reduced food availability than chlorpyrifos. For instance, Singing Bush Larks ate few seeds on the control plot after treatments, and relied primarily on insects. On the chlorpyrifos plots, larks ate about 75 percent insects and 25 percent seeds, but on the high dose fenitrothion plot (2F), larks ate more seeds than insects. These findings suggest larks were forced to eat seeds as insect biomass decreased.

The two insecticides appeared to differ in their impact on birds. Fenitrothion applications resulted in greater decreases in bird numbers. If decreases were caused by reductions in food availability, it follows that fenitrothion must have reduced arthropod biomass to a greater extent than chlorpyrifos. This appears to have been the case. Singing Bush Larks and Abyssinian Rollers consumed primarily grasshoppers in the study area before treatments. After insecticide applications, the acridologists found four to five times as many grasshoppers remained on chlorpyrifos plots as on fenitrothion plots (Chapter VIII). Also, in contrast to the chlorpyrifos plots, grasshopper larvae were absent on fenitrothion plots, and grasshopper recolonization began later and progressed at a slower rate. These findings support the idea that a greater decrease in food resources was responsible for a greater movement of birds from fenitrothion plots and thereby a greater decrease in their numbers.

Insect biomass should increase as insects invade or otherwise reestablish populations on plots. Bird abundance would respond to increased food resources and return to normal. Under such conditions, the effects of treatments should be temporary. Birds are opportunistic in their feeding habits and tend to respond negatively to food decreases and to congregate where food resources are the richest. However, food restrictions can have more serious and long-lasting effects if they occur during the reproductive period and adversely influence nesting success. Observations suggested nesting success of Singing Bush Larks and Buffalo Weavers were affected by fenitrothion treatments. Both species were reproducing during spraying, and their numbers decreased rapidly afterwards. This implied that the insecticide terminated the process of reproduction in some Buffalo Weavers and may have caused some Singing Bush Larks to move before young were fully fledged. Young larks usually leave the nest well before they can fly (Green 1985; Cramp 1988). However, fledgling larks analyzed were debilitated by ChE inhibition, and many probably died on all treated plots. Stromborg *et al.* (1988) dosed nestling European Starlings (*Sturnus vulgaris*) with dicrotophos to examine its influence on postfledging survival and development. They found effects were rapid (death and reduced ChE levels), but survivors recovered rapidly and adverse effects did not extend into the postfledging period.

Birds are not equally exposed to insecticides applied to the environment. Their activities and habits at the time of treatments largely determine the intensity of their exposure. ChE measurements suggested that a few adults of species eating grasshoppers ingested sufficient insecticides to cause intoxication and death. Fledglings, and especially those of the Singing Bush Lark, received high exposure to the insecticides, which resulted in an even greater inhibition of ChE than in adults. However, normal ChE levels of young larks are subject to further study. It has been demonstrated that nestling Starling brain ChE activity was age dependent and increased linearly toward adult levels (Grue *et al.* 1981). As young larks were in grasslands, they were probably subjected to greater dermal contamination than birds active in trees and depressions. Young birds being fed by adults probably were given contaminated insects, as insect protein is a prerequisite for growth in young of most bird species. ChE levels in fledglings decreased substantially during the first 3 days following insecticide treatments.

In Passerines, anorexia is usually observed following sublethal exposure to organophosphorus compounds under laboratory conditions (Grue *et al.* 1982). The significantly lower body masses of flightless fledgling Singing Bush Larks collected 24 and 48 h posttreatment compared to those collected in the control area may have been an effect of exposure to the insecticides. Delayed growth or loss of body mass in nestling songbirds, in the range of 5-25 percent, in the first 24 h after experimental oral exposure to organophosphates has been reported in various studies (Grue and Shipley 1984; Stromborg *et al.* 1988). If the parent birds are also affected by exposure to organophosphates, an even stronger effect on the development of the nestlings may be expected. Female Starlings given an oral dose of dicrotophos made significantly fewer sorties to feed their young and they remained away from their nests longer than controls (Grue *et al.* 1982). ChE levels in some adult Singing Bush Larks in breeding condition indicated that they likely were affected.
ChE measurements in mature birds after insecticide treatments did not indicate serious inhibition at 1 week, and ChE levels in general were near normal after 3 weeks. These findings are consistent with the observation of minimal mortality and debility in adult birds resulting from insecticide applications. Applications of fenitrothion at 300 g/ha in forests of northern Scotland resulted in ChE inhibition in four species of songbirds. Inhibition averaged 47 percent on the day after treatments in one species, and it was still 34 percent after 1 week and 13 percent after 3 weeks in another species (Hamilton *et al.* 1981).

Chlorpyrifos degrades rapidly in birds and residues largely disappear after about 9 h (Odenkirchen and Eisler 1988). In wheat fields treated with 560 and 1,000 g/ha of chlorpyrifos, Horned Larks (*Eremophila alpestris*) showed a 22 percent reduction in ChE after 3 days and only 8 percent after 16 days. No dead larks were found in treated fields (McEwen *et al.* 1986). Our results also indicated ChE inhibition was brief, and mortality in adult birds was low in areas treated with chlorpyrifos.

Residues of 1.0 ppm and higher have been reported from grasshoppers following applications of organophosphate insecticides (Stromborg *et al.* 1984). In consuming their own body mass of grasshoppers carrying 1.0 ppm of fenitrothion residues, birds would ingest 1.0 mg/kg of fenitrothion. Zebra Finches dosed with about 1.0 mg/kg fenitrothion showed 50 percent ChE inhibition (Holmes and Boag 1990). ChE inhibition increased at higher doses, and some mortality occurred. It follows that Singing Bush Larks that consumed their body mass or more in contaminated grasshoppers could possibly suffer ChE inhibition of 50 percent or more and die. Fledgling larks collected on treated plots and showing ChE inhibition of 50 percent or more were apparently debilitated, rather than just flightless, and probably would have died if left in the field.

Conclusions

Fenitrothion and chlorpyrifos treatments to study plots did not cause severe, widespread mortality, but a number of birds were killed. It is doubtful mortality was sufficient to cause measurable decreases in the adult populations of affected species. Decreases found probably resulted from the movement of birds from treated areas in response to a decrease in their supply of insect foods. Decreases in insect biomass and in the proportion of insects eaten by birds were documented and likely were correlated.

The greatest potential for detrimental effects on birds in this study was in limiting reproductive success. Reproducing birds cannot move young and must obtain their foods within a reasonable distance from nests. If inadequate food resources are available, young will fail to mature or adults may desert young to search for better food resources. ChE levels were severely reduced in fledglings, and it is possible that most fledglings on treated plots did not survive. A number of other species, whose reproductive success was not assessed, nested during the study period. Further study of avian reproductive effects in plots treated with fenitrothion would be of high priority in future programs of study in Senegal and throughout Africa where insecticides are applied to control locusts and grasshoppers.

In summary, chlorpyrifos and fenitrothion treatments resulted in temporary decreases in the abundance and changes in the food habits and ChE levels in several bird species. Fenitrothion effects appeared somewhat greater than those of chlorpyrifos. It is possible that both insecticides decreased reproductive success on plots either by reducing numbers of birds fledged or by killing fledglings soon after they left the nest.

The objective of this study was to determine the kinds of effects on birds most likely to result from applications of fenitrothion and chlorpyrifos. Both were felt to be capable of causing considerable direct mortality in birds. This did not prove to be the case. Food resources in treated habitats were reduced, and this caused some species of birds to move in search of food. Those effects appeared to be temporary as insect populations began to increase within several weeks (Chapter IX).

Reproductive effects were apparent and could potentially cause the greatest long-term effects on bird populations. Methods were explored for monitoring performance of breeding birds; such studies should be of priority in future work in Senegal or elsewhere in Africa.

Other insecticides now used for locust control are not expected to cause widespread adult mortality. Their effects, if present, probably would be related to decreases in foods supplies, starvation of nestlings, and poisoning of fledglings. These features should be investigated by monitoring movements of adult birds, reproductive performance in nesting species, and survival of immature birds.

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